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Ingestion and Inhalation dose from dissolved radon in ground waters

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Abstract: *Bore well water samples were collected and analysed for the ^{222}Rn concentration by emanometry method and the concentration ranges from 14.61 - 182.9 Bq L^{-1} with the mean value of 81.4 Bq L^{-1}. The observed concentrations are higher than the Maximum Contaminant Level of 11 Bq L^{-1} as suggested by USEPA. From the measured concentration of ^{222}Rn, the ingestion and inhalation dose and total dose were estimated using the dose conversion factors given by ICRP. The effective dose (ingestion and inhalation) ranges from 117.74 to 1473.44 Sv/y, with 645.15 Sv/y as the average. The observed mean value in the present investigation is slightly higher than the maximum permissible exposure level of 500 μSv/y (exclusively for radon and its daughters) as prescribed by BARC India for Indian environment.*

Key Words: *Bore wells, Emanometry, Ground water, Effective dose.*

1. INTRODUCTION:

Groundwater is enriched with radium and uranium radio nuclides when compared with surface waters especially in mineralised areas. Radium enters groundwater by aquifer solids dissolving, direct recoil across the liquid–solid border during its production by radioactive decay of its parent solid, and desorption. As groundwater moves through fractures in the bedrock that contain radioactive deposits, radioactive minerals can leach out into groundwater system. Wells constructed in bedrock within such areas show elevated levels of natural radioactivity in water quality tests [1].

Radon a daughter product of ^{226}Ra has become one of the major issues in the field of radiation protection over few decades. It is a noble gas having the highest solubility in water with mole fraction value of 0.000125 at 37°C, 15 times higher than that of helium or neon. If the groundwater originates from granitic formations is known to contain higher levels of ^{222}Rn and other radionuclides belonging to the uranium and thorium series [2]. ^{222}Rn in water can get released to indoor air when used in showers, humidifiers, cloth washers, dish washers and cooking *etc*. Ingestion (drinking 222Rn-contaminated water) and inhalation (breathing ^{222}Rn gas which has been released from house hold water) are two ways to be exposed to waterborne ^{222}Rn. Both mechanisms pose potential health hazards [3].

2. STUDY AREA:

The present study area is the granite region of Kanakapura, Ramanagara Taluks, Bangalore rural district and Bangalore city. The geology of this part forms predominantly a granite terrain with numerous varieties of granites, granitic gneiss, pegmatite, charnockites and so on. Closepet granites are the rocks found in the research region. These rocks are younger than the peninsular gneiss. Several varieties of potassium granites with varying colour, texture, and intrusive relationships make up the rocks. Pink, grey, and porphyrite gneisses with massive feldspars, as well as dolerite, are common rocks. These rocks form an N–S band with a width of about 15–25 km. Closepet granite and pegmatite have an uncertain relationship. Closepet granite has been around for 2380 million years. Certain silicon and silica–alkaline igneous rocks contain a high concentration of uranium.

Groundwater is the major source of potable water in this region because of inadequate supply of treated water and the same is also being used for agricultural purposes. As the ground water originates from deep granitic rocks, it may contain elevated concentrations of radioactive elements, which may cause health hazards. Therefore, it was felt worthwhile to undertake a systematic study on ^{222}Rn levels in groundwater of this region and hence the radiation dose to the population of the region including quarry workers.

3. MATERIALS AND METHOD:

With minimal disruption, about 100 mL of water was collected in airtight plastic bottles. There was no headroom in the bottles because they were softly and completely filled. There were extra precautions taken to ensure that there were no air bubbles inside the container, as well as to avoid aeration during the sampling process, which could lead to

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outgassing. The samples were brought to laboratory with least loss of time and were analyzed immediately. The emanometry method was used to calculate the activity concentration of ^{222}Rn in water. In this method about 40 to 60 ml of water sample was transferred into the bubbler by vacuum transfer technique. The dissolved radon in the water was transported to a scintillation cell that had been pre-evacuated and background counted. The scintillation cell was then attached to a photomultiplier and alpha counting assembly after being kept for 180 minutes to allow radon to reach equilibrium with its daughters. The concentration was calculated using the relation shown below [4]. The entire setup was calibrated at EAD, BARC, Mumbai and the average efficiency of the scintillation cells used was found to be 74%. The lowest detectable amount was determined to be 0.041 Bq/l.

$$^{222}\text{Rn Activity} = \frac{6.97*10^{-2}* D}{V * E * e^{-\lambda T} * e^{-\lambda\theta} * (1-e^{-\lambda t})} \quad \text{Bq/l}$$

Where,
D denotes the total number of gross alpha counts above the backdrop
V is the volume of water in radon bubbler (ml)
E is the percentage efficiency of the scintillation cell
λ is the decay constant of radon (2.098×10^{-6} per second)
T is the counting delay in seconds
t is the counting duration (1000 s)
θ is the delay between water sampling and de emanation of radon from water sample to scintillation cell in seconds.

4. RESULTS AND DISCUSSION:

About 15 borewells located near the granite quarries were selected and the water samples collected from these were analyzed for the concentration of dissolved ^{222}Rn and the results are tabulated in column 3 of table 1. The measured concentration ranges from 14.61 - 182.9 Bq L^{-1} with the mean value of 81.4 Bq L^{-1} and the standard deviation of 61.95 Bq L^{-1}. These values are higher than the Maximum Contaminant Level of 11 Bq L^{-1} as suggested by USEPA. The lowest activity of 14.61 Bq L^{-1} was observed at Q5 and the highest was observed at Q15.

Dose due to dissolved ^{222}Rn

From the measured concentration of ^{222}Rn in potable water, the inhalation dose (effective dose to the lung), ingestion dose (effective dose to stomach) and the whole body dose for the population of the region were estimated and are presented in columns 4 – 6 of Table 1. The dose due to ^{222}Rn can be divided into two parts, namely, the dose from ingestion and the dose from inhalation. For the ingestion part, it is expected that ^{222}Rn and its progeny in water impart a radiation dose to the stomach. The conversion factor used for the calculation of effective dose for stomach is 14.4 nSv Bq^{-1} L^{-1} [5].

Table 1: ^{222}Rn activity in ground waters near granite quarries

Sl No	Quarry Code	^{222}Rn Activity (BqL^{-1})	DOSE µSv/y		
			INGESTION	INHALATION	TOTAL
1.	Q1	21.07 ± 0.05	110.73	58.99	169.73
2.	Q2	156.12 ± 0.10	820.57	437.14	1257.71
3.	Q3	64.9 ± 0.07	341.11	181.72	522.83
4.	Q4	97.37 ± 0.08	511.76	272.64	784.39
5.	Q5	182.9 ± 0.11	961.32	512.20	1473.44
6.	Q6	130.95 ±0.09	688.27	366.66	1054.93
7.	Q7	142.05 ± 0.09	746.62	392.74	1144.36
8.	Q8	155 ± 0.15	814.68	434	1248.68
9.	Q9	50.17 ± 0.06	263.72	140.49	404.21
10.	Q10	25.88 ± 0.04	136.07	72.48	208.56

11.	Q11	158.49 ± 0.16	833.02	443.77	1276.79
12.	Q12	38.45 ± 0.05	202.11	107.67	309.72
13.	Q13	16.64 ± 0.03	87.50	46.61	134.12
14.	Q14	37.17 ± 0.05	87.50	46.61	134.12
15.	Q15	14.61 ± 0.03	76.82	40.92	117.74
Range		**14.61 - 182.9**	**76.82 - 961.32**	**40.92 - 512.2**	**117.74 - 1473.44**
Mean		**81.40**	**420.92**	**223.92**	**645.15**
SD		**62.76**	**336.15**	**178.77**	**515.23**

The contribution of dissolved ^{222}Rn in water to indoor ^{222}Rn concentration is dependent on the rate of water use, the volume of the interior environment, and the rate of air exchange. According to UNSCEAR 1 Bq m^{-3} of ^{222}Rn in air with an equilibrium factor of 0.4 and an occupation factor of 0.8, gives an effective dose of 28 μSv y^{-1} to lung. Considering the transfer factor of ^{222}Rn released from water to air to be 1x10^{-4} [3], the conversion factor for unit concentration of ^{222}Rn at equilibrium turns out to be 2.8 μSv /Bq m^{-3}. The effective dosage from the inhalation and ingestion channels was calculated using a tissue-weighting factor of 0.12 for the lungs and stomach. The effective dosage received by the region's population ranges from 117.74 to 1473.44 Sv/y, with a mean of 645.15 Sv/y.

5. CONCLUSION:

The observed concentration of dissolved radon-222 in ground water samples near granite quarries is found to be high when compared to that of some of the other environments and the same may be attributed to the local geology of the region which largely comprises of granite and peninsular gneiss which are known to contain elevated levels of uranium and Thorium series elements. The observed mean value of radon-222 in ground water samples is high compared to the MCL prescribed by USEPA. Consequently, the effective dose to the stomach (ingestion), lung (inhalation) and whole body is found to be high. The mean effective dose received by the quarry workers and population of the region is slightly higher than the maximum permissible exposure level of 500 μ Svy^{-1} (exclusively for radon and its daughters) as prescribed by BARC India for Indian environment.

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